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Performance of Sony's Alloy Based Li-ion Battery

by Donald Foster, Jeff Wolfenstine, Jeffrey Read, and Jan L. Allen

ARL-TN-0319 June 2008

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14. ABSTRACT

Cells from the new Nexelion battery from Sony Corporation were tested for capacity, low temperature performance, high power capability, high temperature storage, rapid recharge and cycle life on deep discharge. The Nexelion 14430 size cells were found to perform equal or better to conventional size 14430 cells in all areas tested but cycle life. The cycle life tests showed that the Nexelion cells loose capacity slightly faster than the conventional cell with deep cycling. However, because of the additional capacity provided by the Nexelion battery chemistry, the Nexelion cell still had more capacity than the conventional 14430 cell after 220 cycles.

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Contents

List of Figures

List of Tables

1. Introduction

The replacement of the pure lithium anodes of rechargeable lithium batteries by carbonaceous lithium insertion negative electrodes in lithium-ion batteries has led to considerable advances in both safety and rechargeability (*1*). Lithium alloys have long been considered as promising negative electrode materials due to their much higher lithium content which provides greater energy density than lithium intercalated carbons. Another possible advantage of lithium alloy negative electrodes is safety due to the generally higher potential of the alloys versus lithium as compared to carbon and the high melting point of most lithium alloys (*2*).

A major problem with lithium alloys as anodes is the very large change in volume on charge and discharge which leads to stresses that cause the alloy to disintegrate and the anode to loose capacity with cycling. Research has established that some improvement in cycle life may be found by starting with nanostructured metal alloy materials to reduce strain and improve cycle life (*3*). Although advances have been made by this approach, nagging problems with capacity fade on cycling have until now prevented any commercialization on a rechargeable lithium battery with alloy anode (*4*).

Sony Corporation of Japan has recently begun marketing a new 14430-size lithium (Li)-ion cell known as "Nexelion[1]" for use in four cell battery packs specifically for powering the company's Handyman camcorder products. Press reports from Sony have claimed for these cells significant advantages over the more conventional Li-ion cells that they replaced (*5*). These included a 30% increase in capacity (910 mAh versus 710 mAh), 20% increase in volumetric energy density (478 Wh/l versus 395 Wh/l) and 10% increase in weight energy density.

In order to determine the new chemistry of the Nexelion cells, the cells were cut open for analysis. The details of the analysis are the subject of an earlier report (*6*). The results showed that the Nexelion anode consists of an equal by weight mixture of graphite and an amorphous alloy phase consisting mainly of a 1:1 alloy of tin and cobalt. The particle size was found to be less than 1 μm. The Nexelion cathode was found to be a two phase mixture. The majority phase was Li_xCoO_2 and the other phase was $Li(Co_yNi_{1.7x}Nn_x)O_2$. The particle size of both phases is in the micron range with many particles of the range between 10 and 20 μm. The conventional cell chemistry has a carbon anode and a Li_xCoO_2 based cathode (*6*).

The marketing of an alloy anode Li-ion cell by Sony could be a historic milestone in the history of battery development. This study will detail the performance characteristics of these cells in the areas of rate capability, capacity, quick charge capability, and high temperature storage.

[1]Nexelion is a registered trademark of Sony Corporation.

2. Experimental

The Sony handyman camcorder pack is shown in figure 1. The plastic casing of the battery pack was cut open to reveal the cylindrical 14430 Nexelion cells. Figure 2 shows one of the Nexelion cells. The dimensions of the cells is shown in table 1. Similarly, the Nexelion camcorder pack previously used to power the camcorder pack, featuring the conventional LiC_6 anode and Li_xCoO_2 cathode battery chemistry were purchased and used as a control on some tests in order to evaluate the Nexelion technology.

Figure 1. Sony handyman camcorder battery.

Figure 2. Sony Nexelion cell.

Table 1. Typical dimensions of a 14430 Nexelion and conventional cell.

Cell Chemistry	Height (mm)	Diameter (mm)	Weight (g)
Nexelion	43	14	20
conventional	43	14	18

The cells were tested on a MAACOR Series 4000 battery test system. A picture of the MAACOR tester is shown in figure 3. The storage testing and low temperature battery testing was done in a Tenney Jr. controlled temperature chamber. The Tenney Jr. temperature chamber is shown in figure 4.

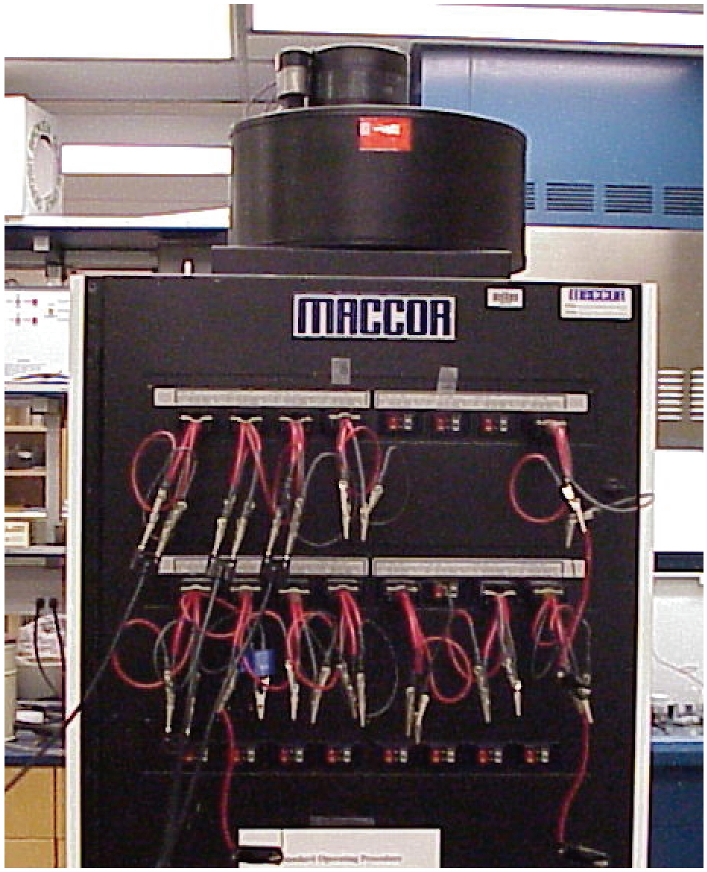

Figure 3. Maccor battery test station.

Figure 4. Tenney environmental chamber.

2.1 Cell Discharge

Figure 5 shows the discharge of a Nexelion battery compared to the conventional 14430 camcorder cell. The discharge rate is C/6 as this is the rate required to power the camcorder. The figure shows that the Sony claim of 30% increased capacity for Nexelion is accurate with the capacity here increasing form 0.65 Ah to 0.92 Ah. The energy density for Nexelion showed a similar improvement over the conventional 14430 cell.

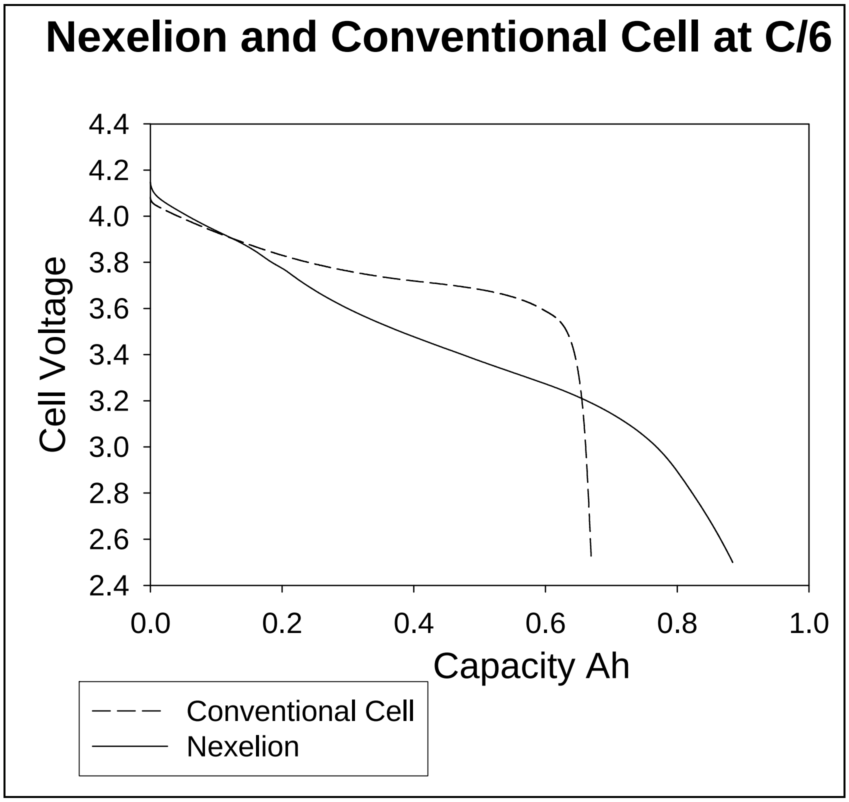

Figure 5. Discharge curve for conventional cell and Nexelion cell.

2.2 Discharge Rate Capability

In order to determine the performance characteristics at higher power drain, the Nexelion battery was discharged at rates varying form C/6 to 2C. Figure 6 shows the results. It can be seen that even the highest rate of discharge tested, 2C, the Nexelion cell has more capacity 0.8 Ah than the conventional cell 14430 tested in figure 1 at the low C/6 rate. This is an excellent result for a cell designed for a low power device, the Handyman Camcorder. The cell was also tested for ability to recharge at higher rates.

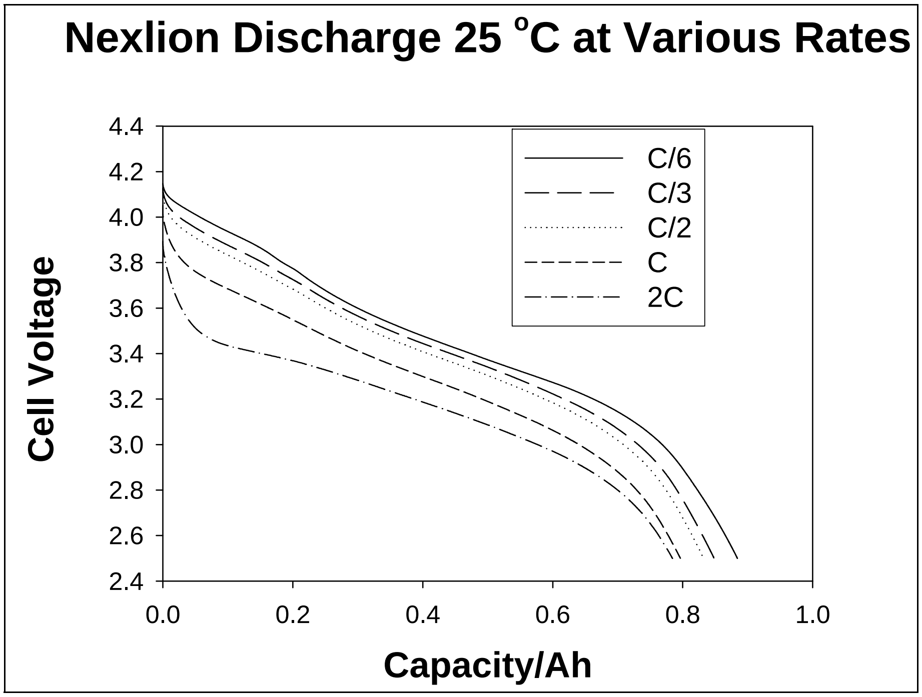

Figure 6. Discharge of Nexelion cell at various rates.

Figure 7 shows the discharge capacity for 5 charge discharge cycles at discharge rates up to 4C. The cells cycled well at all rates tested. In fact the capacity improves slightly with cycle number for the highest rate tested probably due to the cell heating from the very high 4C current discharge.

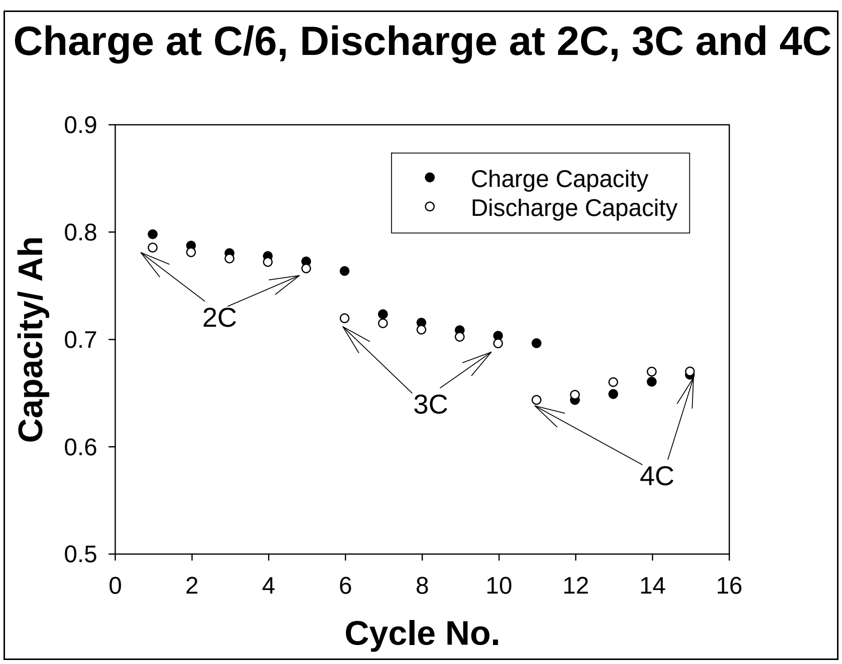

Figure 7. Effect of discharge rate on Nexelion cell cycling.

2.3 Low Temperature Performance

Figure 8 shows the low temperature performance of the Nexelion battery at low temperature. The Nexelion battery has some useful capacity –40 °C at the C/6 rate and is superior to the conventional cell at temperature down to –30 °C. Considering that the low temperature performance can probably be improved through electrolyte selection and cell design, these results suggest that Army low temperature requirements could be met by the new Nexelion battery chemistry.

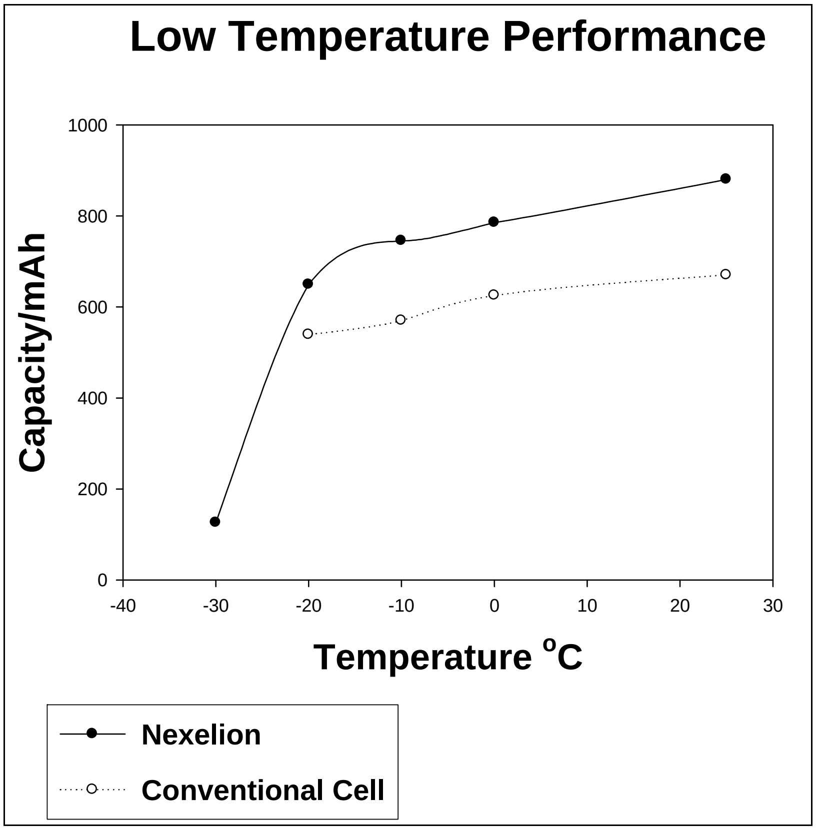

Figure 8. Effect of temperature on discharge cacpacity for Nexelion and conventional cell.

Figure 9 shows the shape of the discharge curves for all temperatures tested in the low temperature performance study.

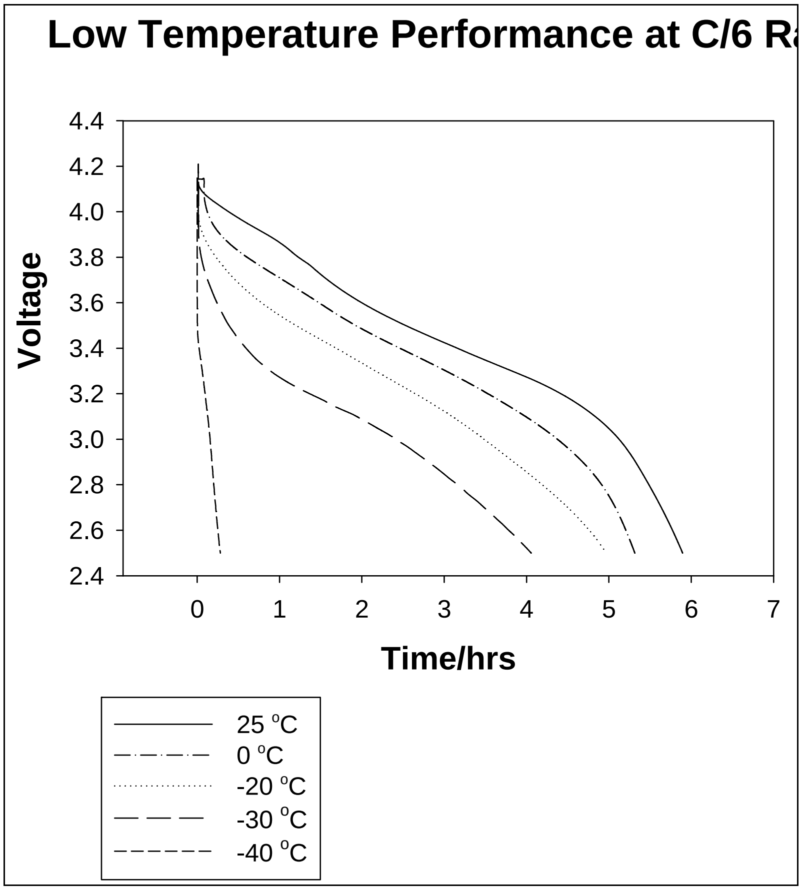

Figure 9. Effect of low temperature on discharge curve of Nexelion cells.

2.4 High Temperature Storage

The high temperature storage characteristics were demonstrated by storing the cells at 60 °C and then cycling the cells at C/6, C/2, C, and 2C. The results shown in figure 10 indicate that even after 3 weeks storage at 60 °C, the Nexelion cell when discharged at C/6 has more capacity than the control cell that was discharged fresh without high temperature storage. This test also shows that the high temperature charge does not prevent the cell from being recharged.

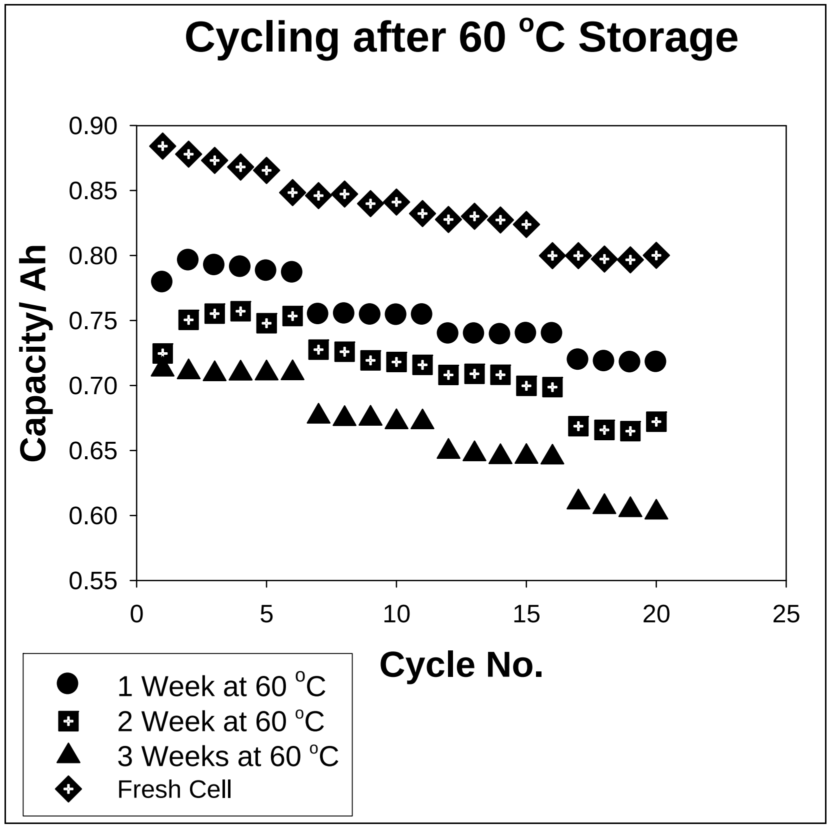

Figure 10. Effect of 60 °C storage on capacity and cycling of Nexelion cells.

2.5 Rapid Recharge

For many applications, to be able to recharge the cell quickly is a very important benefit. However, with carbon electrodes, rapid recharge frequently results in plating of dendritic lithium on the anode surface which can eventually result in cell shorting internally and an unsafe condition, especially if the cell becomes too hot and the lithium melts. Figure 11 shows the results for recharge rates as high as 4C. The cell does not lose capacity over the large variation of charge rates from C/6 to 4C.

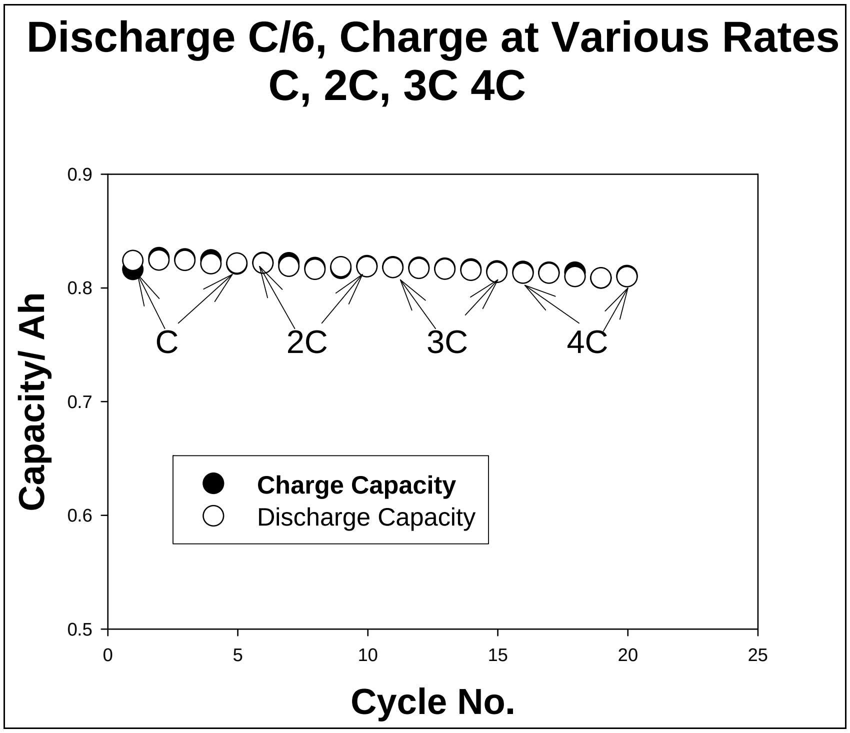

Figure ll. Effect of charge rate on capacity of Nexelion cells.

2.6 Cycle Life

The cycle life has long been known to be the main problem with alloy anode cells. Figure 12 shows the capacity versus cycle number curve for the Nexelion cell and for the control cell. Capacity of the Nexelion cell falls with cycling faster than the carbon anode control cell, but because the Nexelion cell has a high initial capacity, the capacity of the Nexelion cell remains higher than the control throughout the test which was 200 cycles. The Army requirement for rechargeable batteries is no more than 10% capacity loss over 220 cycles.

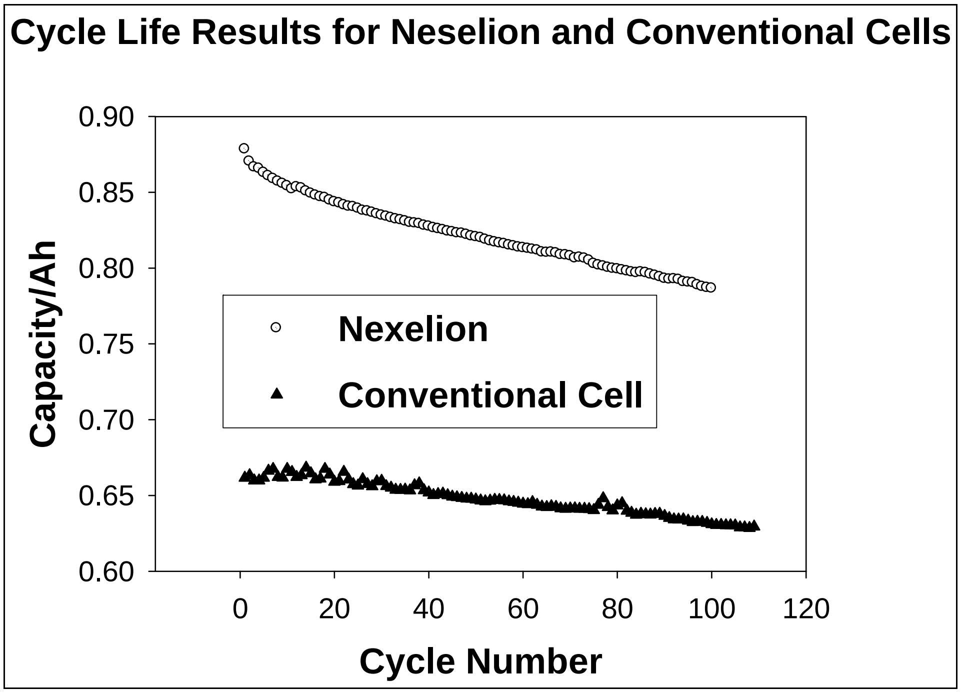

Figure 12. Capacity versus cycle number for Nexelion cell and conventional cell.

Figure 13 shows that the Nexelion cell does not meet this requirement, crossing the 10% capacity loss marker after 100 cycles.

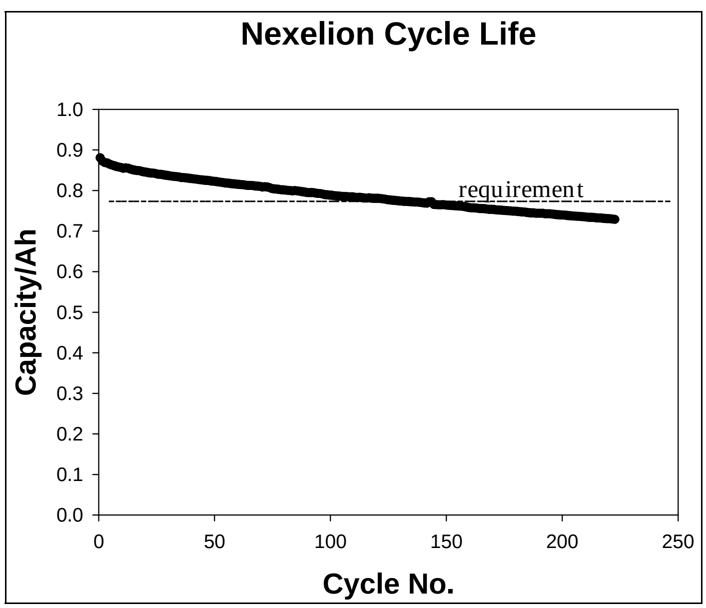

Figure 13. Evaluation of the Nexelion battery for the Army cycle life requirement.

3. Conclusion

The Sony Nexelion battery which uses a negative electrode based on a composite of amorphous phase of a tin and cobalt alloy with carbon has shown remarkably good performance in all areas of our test. Sony's claims of 30% improved capacity, 20% improved volumetric energy density, and 10% increased weight energy density were shown to be true. Our results have also shown that the cell has good storage characteristics at 60 °C, comparable low temperature performance to –30 °C to the conventional cell, and can withstand rapid charge and discharge at up to 4C rate for at least 5 cycles. Although we did not investigate high rate performance over many cycles, the 14430 cell is designed for the low power camcorder device. Therefore, further improvements in rate could be achieved with a high power cell design with this cell chemistry.

The Nexelion cycle life does not meet the Army mil Spec of less than 10% capacity loss after 220 charge-discharge cycles. However, because the Nexelion has higher capacity initially than the conventional cell, the Nexelion is able to complete the 220 cycles with more capacity than the initial capacity of the conventional cell. For this reason the Nexelion could be considered for Army applications requiring long cycle life.

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